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ABSTRACT

This report contains a comparative analysis of the differential effectiveness of computer-assisted instruction (CAI), programmed instructional text (PIT), and lecture methods of instruction in three medical courses--Medical Laboratory, Radiology, and Dental. The summative evaluation includes (1) multiple regression analyses conducted to predict learner performance; (2) 2x3 analyses of variance conducted to investigate treatment (CAI, lecture, and PIT) and aptitude effects; and (3) discriminant analyses of high-fast and low-slow achievers in each group to determine the characteristics of learners for whom the particular treatment was effective. The data for each course are presented, including charts and graphs, followed by a section providing discussions of the instructional effectiveness of the three treatments within each course; decision strategies; learner characteristics; characteristics of high achievement--fast CAI learners, high-fast vs. low-slow PIT students, and high vs. low achievement lecture students; post instructional attitudes; learner media preferences; and attitude change. Conclusions, recommendations, and a list of references conclude the report. (CHC)

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AIR FORCE HUMAN RESOURCES LABORATORY

COMPUTER-ASSISTED, PROGRAMMED TEXT, AND LECTURE MODES OF INSTRUCTION IN THREE MEDICAL TRAINING COURSES:

COMPARATIVE EVALUATION

By

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Final Report

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This final report was submitted by the Technical Training Division, Air Force Human Resources Laboratory, Lowry Air Force Base, Colorado 80230, under Project 1121, with HQ Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235. Dr. Gerard Deignan (TTT) was the Principal Investigator for the Laboratory.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

MARTY R. ROCKWAY, Technical Director
Technical Training Division

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Commander

PREFACE

Numerous individuals contributed significantly to the planning, conduct and evaluation of this jointly sponsored Air Force and Defense Advanced Research Project Agency (DARPA) investigation. The personal and professional commitment of the Air Training Command Surgeon General, General J. E. Wesp, to the 1976-77 phase of the program contributed significantly to the progress. Similarly, Dr. Harold O'Neil's DARPA support funds for the same period reflect favorably upon his agency's research investment acumen.

The Air Force School of Health Care Sciences PLATO IV Author Development Team, including Major Roseman, Major LaCoe, Captain Eyl, and Captain Gage, effectively worked with health care subject matter experts and the authors in developing instructionally effective CAI. The authors' gratitude is also expressed to Captain Horowitz, and SSgt Fincher who with the authors jointly conducted, on-site summative evaluation functions.

Acknowledgment of the professional and technical support provided by Lt Col Gullatt, DDS, and his Dental course staff for being the first to innovate with CAI. Lt Col McKessick, and Lt Col LaHood supported by their Medical Lab staff, and CMSgt Denny and his capable Radiology staff also deserve recognition for their contributions. Though never recognized last among his peers, Lt Col Lindsley was peerless in leadership and management support of this project. The manuscript benefited from the reviews of several individuals, and some of Lt Col Waters' suggestions made substantive contribution. Additionally, Larry Davis and Mikio Kusumoto provided exceptionally professional graphic and photographic support. A1C Duncan also competently conducted numerous statistical programs.

Finally, it is to the Air Force students to whom we owe a great debt for improving our knowledge of individual differences in learning, motivation, and performance on diverse tasks within computer-based environments.

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COMPUTER-ASSISTED, PROGRAMMED TEXT, AND LECTURE MODES OF INSTRUCTION IN THREE MEDICAL TRAINING COURSES: COMPARATIVE EVALUATION

I. INTRODUCTION

Comparative analyses of the differential effectiveness of computer-assisted instruction (CAI), programmed instructional text (PIT), and lecture methods of instruction in field settings have been sparse and sometimes equivocal (Dallman & DeLeo, 1977; Dare, 1975; Keesler AFB, 1974). Presently, it is not known whether one instructional method is more effective than another for certain kinds of students confronted by different tasks nor the degree of effectiveness. Rather, it is assumed that (a) learners possess and employ to a similar degree the same characteristics for processing information and (b) instructional methods/media are equally effective for different kinds of tasks and students despite the vast literature on individual differences and task difficulty.

This report attempts to provide information in the medical training area on the following questions: (a) Do CAI, PIT, and lecture differ in instructional effectiveness? and (b) Under what conditions are CAI, PIT, and lecture differentially effective?

Objectives

The major objectives of this field study were to compare CAI with lecture and PIT modes of instruction on dimensions of (a) instructional effectiveness, (b) time-savings, and (c) student acceptance. Additionally, pre-course assessment measures were used to attempt to identify the characteristics (e.g., aptitude, biographical data, and attitudes) of learners for whom CAI, PIT and lecture modes of instruction might be differentially effective in segments of three different training courses for medical technicians.

II. METHOD

Students

Three medical training courses (Medical Laboratory, Radiology, and Dental Assistant) were selected to provide a range of learner characteristics and course content suitable for generalizing results to students in medical courses of comparable difficulty. The Medical Laboratory course represented a difficult course requiring a relatively high aptitude level. Radiology and Dental courses, respectively, corresponded to average and low difficulty courses, with corresponding aptitude levels. The student sample during formative and summative evaluation consisted of 700 male and female trainees assigned to the Air Force School of Health Care Sciences at Sheppard AFB. The CAI delivery system used was the PLATO-IV interactive Plasma Panel terminal connected to a main frame at the Center for Education Research Laboratory (CERL), University of Illinois, Champaign-Urbana via telephone line. The programming language used in PLATO was TUTOR, a language providing realtime author editing as well as CAI delivery. Instructional materials from each of the courses were developed in CAI formats by on-site experts trained in TUTOR.

Pre-Course Measures

Based upon training task analyses in each course, selected pre-course learner characteristics measures were developed and administered via automated slide-tape to all students prior to course

entry. These measures include (a) the medical version of the Delta Reading Vocabulary (r_{yy} =.88) (Deignan, 1973), (b) the General Aptitude Index from the Armed Services Vocational Aptitude Battery (ASVAB) (r_{yy} = .87), and (c) the memory (r_{yy} = .66), visualization (r_{yy} = .77), and biographical measures from the Delta Training Aptitude Battery (Deignan, 1976). In addition to validity studies of the Delta currently in progress in both military and civilian environments, previous studies. (Collins, Dansereau, Holley, McDonald, & Garland, 1978; Dansereau, et. al., 1973, 1975, 1978; Deignan & Duncan, 1977; Diekhoff, 1977; McCoombs, Deignan, & Siering, 1975; Moore, 1975; and Long, 1976) have reported predictive validities ranging from r =.45 to r =.75 in studies employing university or military students from a variety of courses. Measures were administered prior to course entry to aid CAI authors in the development and formative evaluation of instructional material appropriate to the target population in each course. These control measures were subsequently used to assist summative evaluation in terms of explaining, interpreting, and generalizing comparative performance results.

Materials Development Procedure

Prior to CAI lesson development, prediction of course criterion achievement from pre-course learner characteristics was accomplished by means of multiple regression analyses. By trichotomizing the distribution of the highest aptitude predictor of achievement (Delta Reading Vocabulary), low, middle, and high aptitude groups were formed for each course. Criterion-related learner characteristics were used to assist CAI authors in the initial development of instructional materials and strategies appropriate to the target population in each course. Hence, CAI materials development and validation were based upon a student profile of characteristics known to be related to course achievement. This approach, therefore, prepared authors for the range of learner skills, aptitudes, and attitudes for which instruction was intended. Likewise, pre-course learner characteristics information suggested how authors might best design CAI lessons and branches to cope with such factors as: (a) deficient reading skills, (b) concentration-retention capabilities, (c) learner strategies for processing information, and (d) initial motivational level. Similarly, to assist formative evaluation, all CAI students in the three courses were administered an on-line attitude survey which contained Likert-type items with response alternatives ranging from highly unfavorable (e) to highly favorable (a).

Formative Evaluation

Formative evaluation consisted of an experimental period of initial instructional materials development characterized by lesson and test development, materials tryout, and subsequent instructional revision. Small numbers of students were administered newly developed lessons to provide CAI authors with student attitudes toward CAI. Following small group lesson revision, large group pilot studies were conducted on representative samples of students from each course: (a) to ensure lessons satisfactorily supported attainment of instructional objectives, (b) to provide preliminary statistical data on representative student performance, e.g., achievement scores, time to completion, and embedded lesson test item statistics keyed to specific instructional lesson segments, and (c) to further individualize instruction by such means as compensatory branches, additional drill and practice or examples, and graphic simulations.

Summative Evaluation

In contrast to formative evaluation, summative evaluation initiated a period in which all instructional materials, procedures, and evaluation measures remained constant. Comparison between CAI and non-CAI delivery (lecture or PIT) was made on identical instructional objectives

and criterion measures (Table 1). Criterion measures included post-instructional measures of achievement, elapsed time to complete instruction, and attitudes toward CAI, PIT, and lecture. One hundred students were programmed for assignment to each CAI and non-CAI control condition in each course during summative evaluation. In some analyses, the sample size was less than 100 subjects per condition because some students lacked complete data on pre-course assessment and/or criterion data.

Table 1. **Sample Cell Size by Course, Treatment and Aptitude Levels**

Course	Treatment N	Aptitude – Treatment[a] Low	Middle	High
Medical Lab				
CAI	93	34	36	26
Lecture	98	30	36	32
Radiology				
CAI	97	34	33	20
PIT	89	24	30	15
Dental				
CAI	101	30	28	21
Lecture	52	7	7	9

[a]The sum of the cells in each row does not equal the total treatment N due to the exclusion of students who were not administered the pre-course assessment measures.

Major statistical analyses included: (a) multiple regression analyses conducted to predict learner performance, (b) 2 x 3 analyses of variance conducted to investigate treatment (CAI, lecture, and PIT) and aptitude effects, to include possible interactions between treatments and aptitude levels, and (c) discriminant analyses of high-fast and low-slow achievers in each treatment to determine the characteristics of learners for whom CAI, PIT, and lecture were effective.

III. RESULTS

To compare within-course CAI and non-CAI Instructional effects at low, middle, and high reading vocabulary aptitude levels, 2 x 3 analyses of variance were performed in each course separately. To compare time-to-completion differences between constant time lecture treatments and variable time CAI treatments, the standard error of the difference scores at each aptitude level was determined to be the appropriate statistical analysis (Pennell, 1978). Appendix A includes the achievement cell mean (X) and the standard deviation (Sd) by aptitude, treatment, and course. Appendix B includes the time-to-completion cell $\overline{X}$ and Sd by aptitude, treatment, and course. Appendix C includes the overall main effect $\overline{X}$ and Sd independent of aptitude.

Medical Laboratory

In the Medical Laboratory course, the 2 x 3 analysis of variance of achievement scores, as shown in Table 2, revealed significant main effects for both treatments, $F(1,177) = 54.51$, $p \leq .001$, and aptitude, $F(2,177) = 5.41$, $p \leq .01$. Graphic illustration of the data is shown in Figure 1.

Table 2. **Analysis of Variance of Achievement Scores for Lecture-CAI Treatments and Aptitude Level Conditions in the Medical Laboratory Course**

Source	df	Sum of Squares	Mean Square	F
Main Effects				
CAI vs. Lecture (A)	1	236.306	236.306	51.51**
Aptitude (B)	2	46.922	23.461	5.11*
A + B Interaction	2	5.725	2.863	.660
Within	177	767.359	4.335	
Total	182	1,057.770		

*p ≤.01.
**p ≤.001.

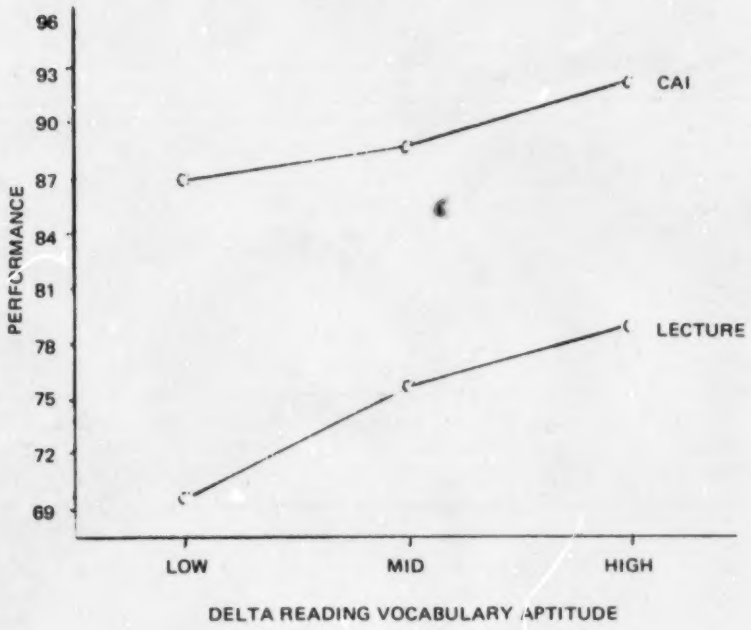

Figure 1. **Medical Laboratory achievement as a function of aptitude level and CAI vs. lecture conditions.**

Inspection of Figure 1 reveals the average achievement of CAI students was 18 percentage points higher, $t(1,53) = 5.21$, $p \leq .001$, than lecture controls at the low aptitude level. Similar CAI achievement superiority in comparison to Medical Laboratory lecture controls was also reflected at the middle aptitude (88% vs 75%), $t(1,71) = 4.14$, $p \leq .001$, and high aptitude levels (92% vs 79%), $t(1,57) = 3.49$, $p \leq .001$.

Time-to-completion difference scores (Table 3) between Medical Laboratory lecture and each CAI aptitude level revealed significant differences in favor of CAI at the mid ($t(1,70) = 2.31$, $p \leq .02$) and high aptitude CAI levels, $t(1,56) = 7.84$, $p \leq .001$. The time difference at the low aptitude level was not significant. However, as noted above, the achievement of the low aptitude CAI students was significantly better than their lecture controls. In fact, as shown in Figure 1, the average achievement of the low aptitude CAI students is higher than that of both the mid and high aptitude lecture students. Thus, it is probable that if all groups had been trained to the same criterion level, there would have been a significant time savings in favor of CAI at all levels.

The CAI-lecture treatment by aptitude time difference scores shown in Figure 2 indicated CAI time savings exceeded 11% at the mid and 33% at the high aptitude levels within the Medical Laboratory course.

Table 3. **The Grand Mean of Difference Scores and the Standard Error of the Difference Scores to Test the Difference between Lecture Time to Complete (a constant of 540) and CAI Time to Complete Instruction at Three Aptitude Levels in the Medical Lab Course**

$\bar{X} = 76.000$	Low Aptitude Time Difference = -32.0476
Sd = 226.091	Middle Aptitude Time Difference = 56.6410
Se = 24.523	High Aptitude Time Difference = 192.3077
n = 86 CAI	
	t (Low apt) = 1.31
	t (Mid apt) = 2.31*
t = 76/24.523	t (High apt) = 7.84***
t = 3.10**	

*p ≤.05.
**p ≤.01.
***p ≤.001.

Radiology

The 2 x 3 analysis of variance of achievement scores within the Radiology course is shown in Table 4. In addition to a statistically significant aptitude main effect, $F(2,149) = 6.26$, $p \leq .01$, a significant CAI-PIT treatment x aptitude interaction, $F(2,149) = 9.22$, $p \leq .001$, was found. However, the CAI vs. PIT main effect comparison was not significant ($p \leq .07$).

Inspection of the interaction shown in Figure 3 revealed low aptitude CAI students scored 7 percentage points higher, $t(1,57) = 2.56$, $p \leq .01$, in achievement than did low aptitude PIT students. No statistically significant treatment differences were found at the middle aptitude level; however, high aptitude CAI achievement was 9 percentage points greater, $t(1,26) = 2.70$, $p \leq .01$ than high aptitude PIT controls.

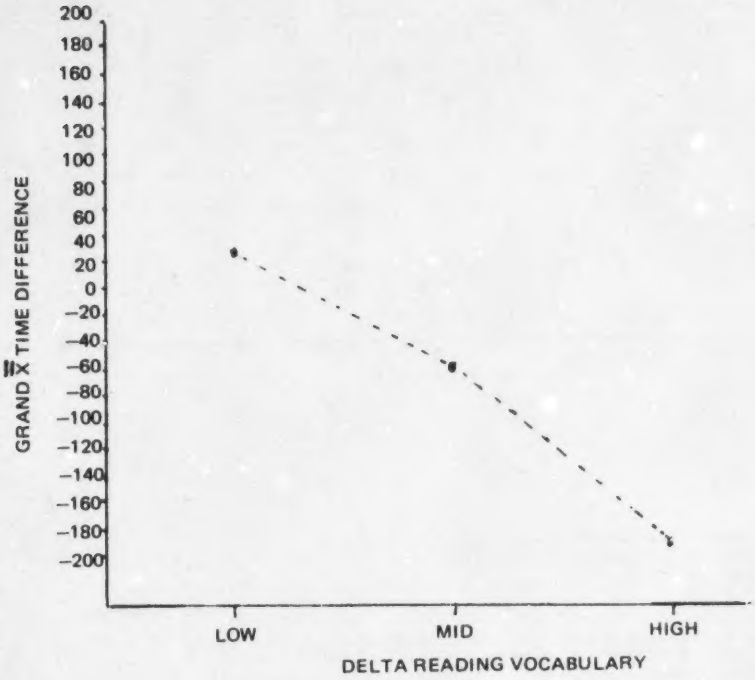

Figure 2. **Medical Laboratory CAI time to completion differences from the $\bar{X}$ as a function of reading vocabulary level.**

Table 4. **Analysis of Variance of Achievement Scores for PIT-CAI Treatments and Aptitude Level Conditions in the Radiology Course**

Source	df	Sum of Squares	Mean Square	F
Main Effects				
CAI vs. PIT (A)	1	42.700	42.700	3.31
Aptitude (B)	2	161.716	80.858	6.26*
A + B Interactions	2	238.107	119.054	9.22**
Within	149	1,922.588	12.903	
Total	154	2,371.187		

*p ≤.01.
**p ≤.001.

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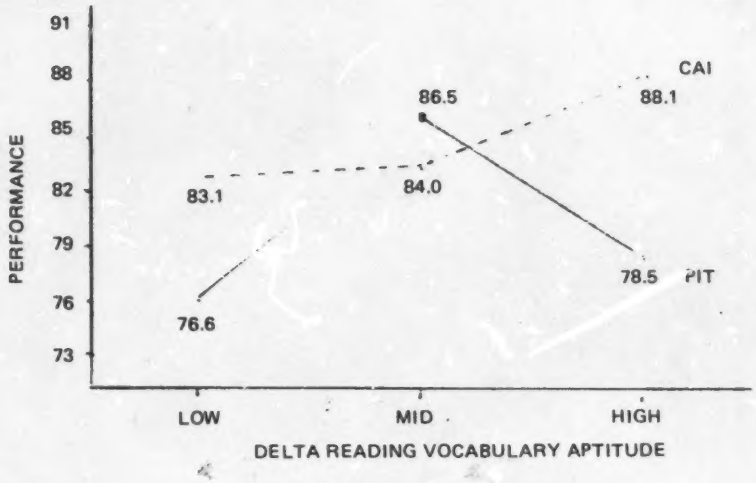

Figure 3. **Radiology achievement as a function of aptitude level and CAI vs. PIT conditions.**

In Table 5, 2 x 3 analysis of variance of time-to-complete instruction in the Radiology course revealed a significant main effect for aptitude, $F(2,143) = 9.13$, $p \leq .001$, and a significant CAI-PIT treatment x aptitude interaction, $F(2,149) = 6.69$, $p \leq .01$. The main effect for treatment approached, but did not reach, significance ($p \leq .09$).

Table 5. **Analysis of Variance of Time to Complete Instruction for PIT-CAI Treatments and Aptitude Level Conditions in the Radiology Course**

Source	df	Sum of Squares	Mean Square	F
Main Effects				
CAI vs. PIT (A)	1	16,435.744	16,435.744	2.84
Aptitude (B)	2	105,504.284	52,752.142	9.13**
A + B Interactions	2	77,307.475	38,653.738	6.69*
Within	149	860,784.957	5,777.080	
Total	154	1,071,381.510		

*$p \leq .01$.
**$p \leq .001$.

Low aptitude CAI students demonstrated a 17% savings in time to complete instruction, $t(1,53) = 2.33$, $p \leq .02$, when compared to their low aptitude PIT counterparts, as depicted in Figure 4. The tendency of high aptitude CAI students to progress faster than high aptitude PIT students was not statistically significant, $t(1,56) = 1.65$, $p \leq .12$. This result may in part be due to the greater

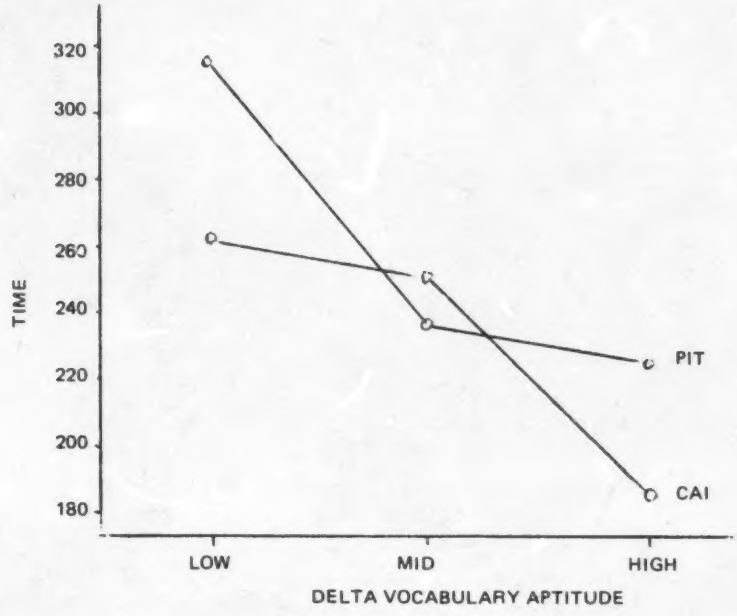

Figure 4. **Radiology time to completion as a function of aptitude level and CAI vs. PIT conditions.**

completion time variance of the PIT students (Sd =86.89) in comparison to CAI student (Sd = 46.54) variance. (However, here again, the CAI time savings probably would have been significant had the level of achievement been controlled.)

Dental Course

Dental course 2 x 3 analysis of variance of achievement is reported in Table 6. Only the main effect for aptitude level was statistically significant, $F(2,96) = 7.38$, $p \leq .001$.

Graphic representation of the Dental CAI-lecture treatment by aptitude level effects shown in Figure 5 revealed that low aptitude CAI students tended to score 7 percentage points higher than low aptitude lecture controls. Due to the joint effects of moderate achievement criterion reliability (r_{yy} = .58) and lack of low aptitude-criterion score matches, the small sample (N =7) at the low aptitude lecture level in contrast to the low aptitude CAI sample size (N =30) may have precluded statistical significance, $t(1,35) = 1.27$, $p \leq .21$.

Table 6. **Analysis of Variance of Achievement Scores for CAI-Lecture Treatments and Aptitude Level Conditions in the Dental Course**

Source	df	Sum of Squares	Mean Square	F
Main Effects				
CAI vs. Lecture (A)	1	66.69	66.69	.42
Aptitude (B)	2	2.336.49	1.168.25	7.38*
A + B Interaction	2	271.23	135.61	.86
Within	96	15.178.51	158.1	
Total	101	17.796.08	176.20	

*p ≤.001.

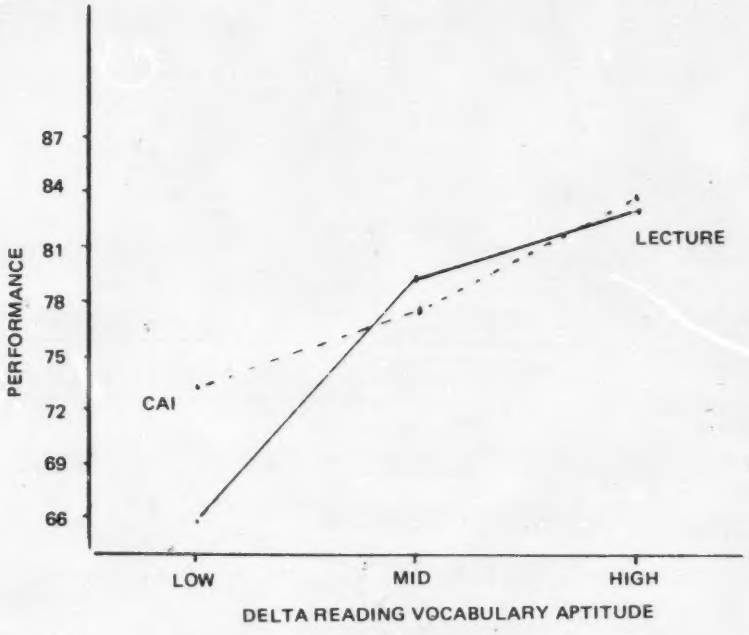

Figure 5. **Dental achievement as a function of aptitude level and CAI vs. lecture conditions.**

Analysis of time (Table 7) to complete instruction within the Dental course resulted in statistically significant differences in time at each aptitude level. Examination of time to completion (Figure 6) revealed high aptitude CAI students completed instruction in 29% less time, $t(1,30) = 13.52$, $p \leq .001$), middle aptitude students in 15% less time, $t(1,34) = 7.38$, $p \leq .001$, and low aptitude students in 9% less time, $t(1,36) = 3.81$, $p \leq .001$ than lecture controls.

Table 7. The Grand Mean of Difference Scores and the Standard Error of the Difference Scores to Test the Difference between Lecture Time to Complete Instruction (a constant of 540) and CAI Time to Complete Instruction at All Aptitude Levels in the Dental Course

$\bar{X}$ = 86.6962	Low Aptitude Time Difference = 43.1667
Sd = 100.6172	Middle Aptitude Time Difference = 83.5714
Se = 11.3203	High Aptitude Time Difference = 153.0476
n = 79 CAI	
	t (Low apt) = 3.81*
	t (Mid apt) = 7.38*
t = 86.6962/11.3203	t (High apt) = 13.52*
t = 7.66*	

*p ≤.01.

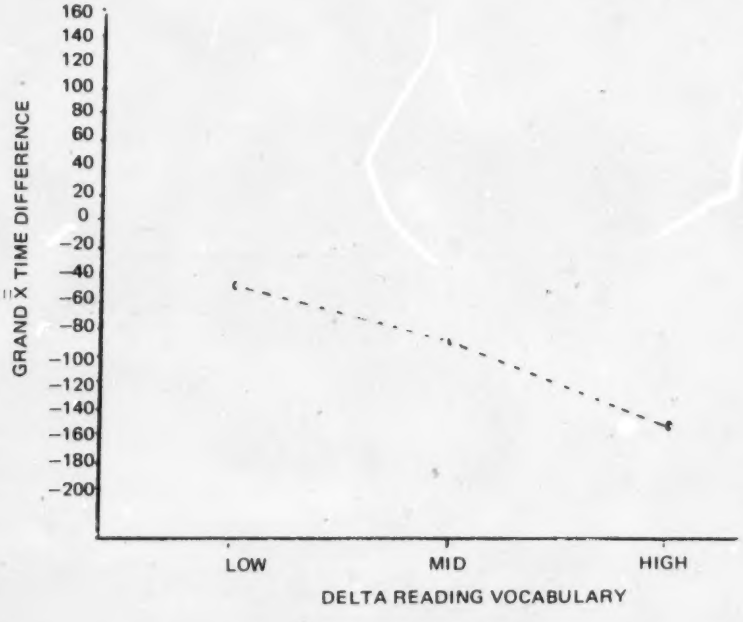

Figure 6. Dental CAI time to completion differences from the $\bar{X}$ as a function of reading vocabulary level.

Additional Learner Characteristics Variables

In addition to reading vocabulary aptitude, pre-course measures of motivation, self-concept, cognitive styles, learner strategy preference for processing information and related biographical data were expected to be related to achievement and time-to-complete instruction. Accordingly, multiple stepwise regression analyses between achievement and pre-course learner characteristics in each course were conducted and cross-validated.

Within the Medical Laboratory course, the chief variables predictive of achievement included reading vocabulary, motivation (level of aspiration to achieve), self-concept, and learner strategies for processing information. ($R = .61$, $p \leq .001$). Cross-validation of the multiple correlation on an independent, hold-out sample revealed little shrinkage ($R = .55$, $p \leq .001$).

Figure 7 depicts CAI and lecture achievement score differences as a function of treatment and learner strategy preferences for processing information by rote, imagery, or verbal paraphrasing. Analysis of variance of achievement score differences resulted in statistically significant main effects for treatment, $F(1,176) = 49.62$, $p \leq .001$ and strategy preferences, $F(2,176) = 3.12$, $p \leq .05$. The greatest difference in achievement between CAI and lecture controls was obtained by learners who preferred imagery. In this case, the achievement of the CAI group exceeded that of its corresponding lecture group by 19 percentage points. As noted in Figure 7, CAI rote learners exceeded the achievement of lecture controls by 17 percentage points, whereas CAI learners who preferred verbal paraphrasing excelled lecture counterparts by 12 percentage points.

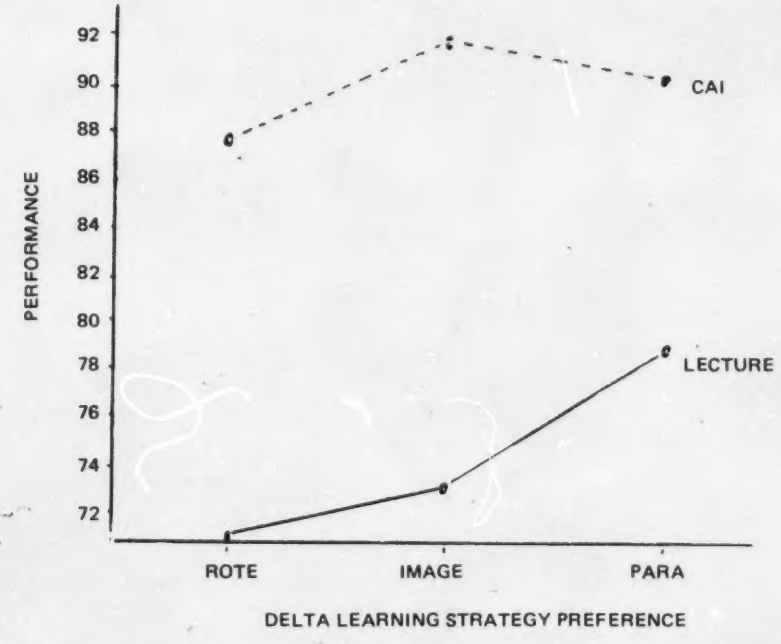

Figure 7. **Medical Laboratory achievement as a function of learner strategy preference for processing information and CAI vs. lecture conditions.**

Variables predictive of time to completion in the Medical Laboratory course included reading vocabulary, self-reliance, field independence, self-concept, memory, and learner strategy preferences ($R = .65$, $p \leq .001$). Validation of the multiple correlation on an independent sample produced slight shrinkage in the cross-validation group ($R = .61$, $p \leq .001$). One of several learner characteristics found significantly related to time savings included self-concept measures from the Delta Biographical Inventory. Time-to-completion differences between CAI and lecture as a function of low, middle, and high self-concept are shown in Figure 8.

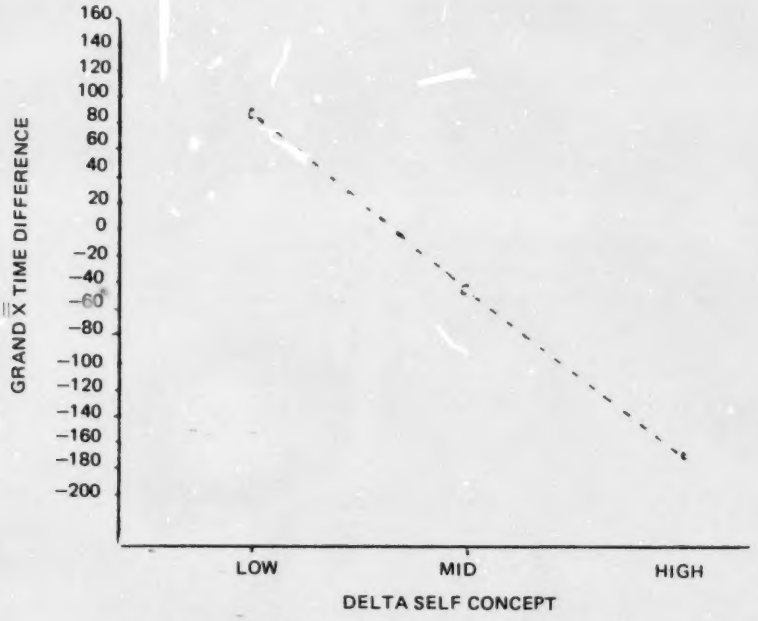

Figure 8. CAI time to completion differences from the $\bar{\bar{X}}$ as a function of self-concept level in the Medical Laboratory course.

Time to completion as a function of treatment and self-concept is shown in Figure 8. High self-concept CAI students completed instruction in 32% less time, $t(1,20) = 5.04$, $p \leq .0001$, as a function of CAI than did Medical Laboratory lecture controls.

Within the Radiology course, learner characteristics predictive of achievement included reading vocabulary, memory, level of achievement aspiration, independence, learner strategy preferences, and attitudes toward reading ($R = .65$, $p \leq .001$). Cross-validation of the multiple correlation on the hold-out group indicated some shrinkage, ($R = .49$, $p \leq .001$), in predicting an achievement criterion of moderate reliability ($r_{yy} = .56$). Figure 9 depicts treatment achievement score differences as a function of three levels of achievement aspiration.

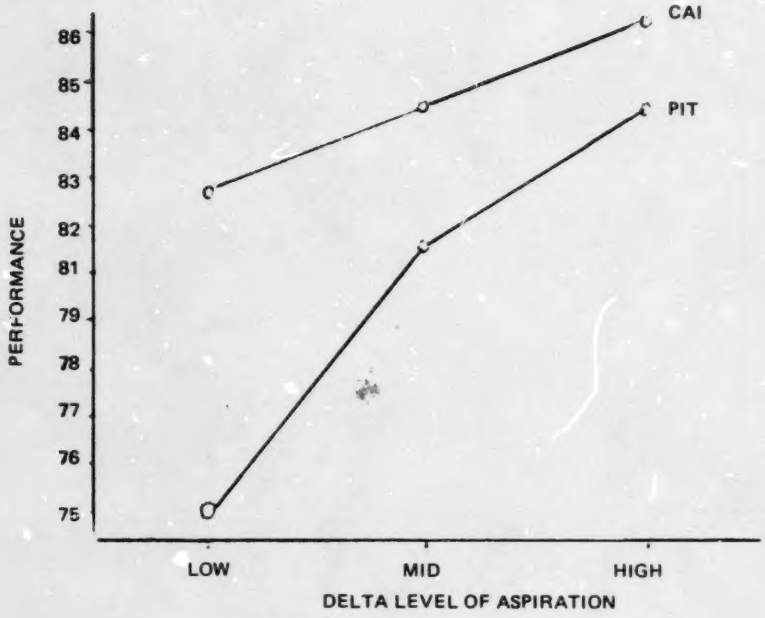

Figure 9. **Radiology achievement as a function of level of aspiration and CAI vs. PIT conditions.**

Statistically significant main effects were obtained for the CAI-PIT treatment, $F(1,134) = 4.95$, $p \leq .05$, and achievement motivation factors, $F(2,134) = 3.95$, $p \leq .05$. Low achievement aspiration CAI students exceeded the achievement of low aspiration PIT students by 6 percentage points, $t(1,36) = 1.79$, $p \leq .05$, as shown in Figure 9.

Learner characteristics predictive of Radiology time to completion included reading vocabulary, memory, self-estimates of memory, self-reliance, self-concept, and learner strategy preference ($R = .60$, $p \leq .001$). Shrinkage of the multiple correlation was acceptable, ($R = .54$, $p \leq .001$). One of several learner characteristics found related to completion time was learner self-estimates of memory when confronted with lengthy or complex material, as shown in Figure 10.

Analysis of variance of time as a function of treatment and learner self-estimates of memory resulted in statistically significant main effects for treatment, $F(1,137) = 6.30$, $p \leq .01$, and memory, $F(2,137) = 7.10$, $p \leq .001$. Average memory CAI students completed instruction in 20% less time than PIT counterparts as shown in Figure 10.

Dental course learner characteristics predictive of achievement included reading vocabulary, memory, achievement aspiration, self-concept, learner strategy preferences, and ordinal birth rank in one's family ($R = .67$, $p \leq 001$). Shrinkage of the multiple correlation was acceptable ($R = .60$, $p \leq .001$). Similarly, variables predictive of time to completion included reading vocabulary, achievement aspiration, self-concept, and learner strategy preferences ($R = .68$, $p \leq .001$). Cross-validation yielded slight shrinkage ($R = .62$, $p \leq .001$). Accordingly, Figure 11 graphically displays time-to-completion differences as a function of treatment and three levels of achievement aspiration: low, middle, and high levels of aspiration prior to assignment to CAI or lecture conditions.

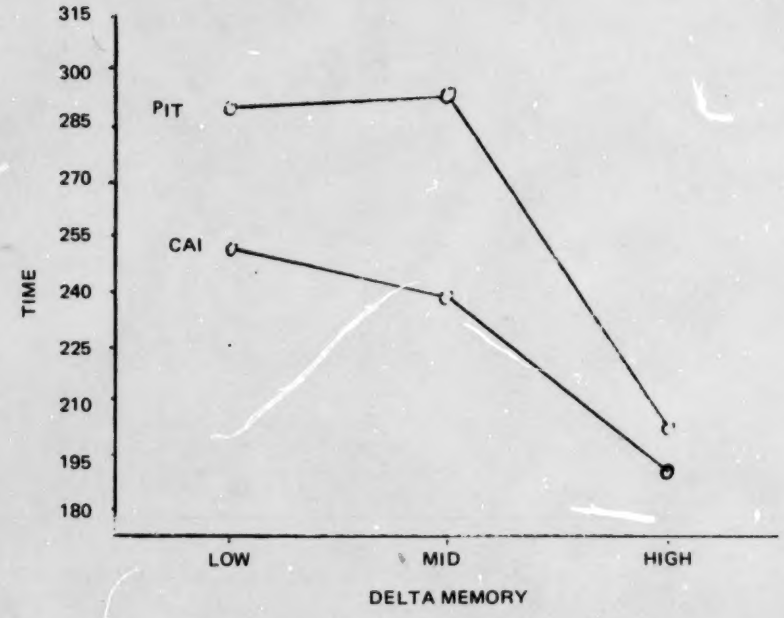

Figure 10. **Radiology time to completion as a function of learner's self-estimate of memory capability and CAI vs. PIT conditions.**

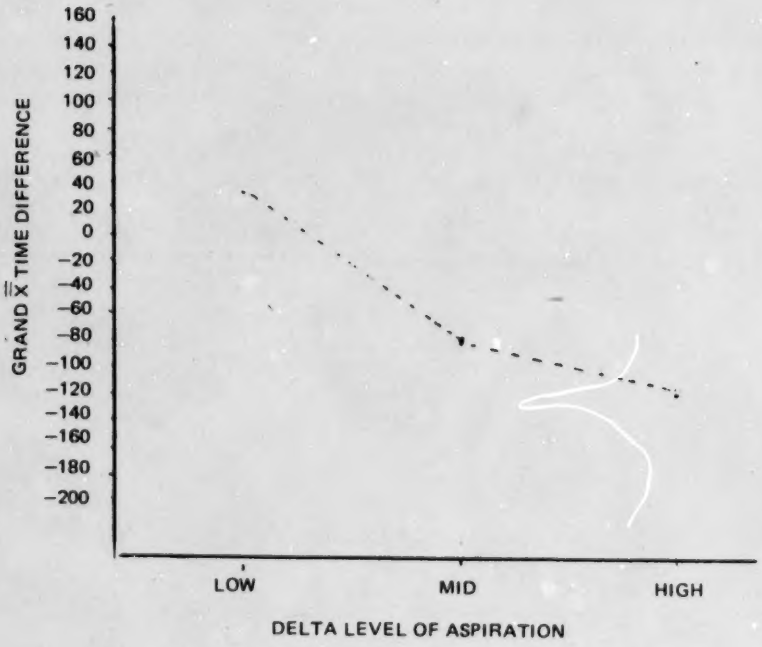

Figure 11. **CAI time to completion differences from the $\bar{\bar{X}}$ as a function of level of aspiration in the Dental course.**

Dental course time to completion revealed statistically significant effects for CAI-lecture treatments and motivation. As shown in Figure 11, high aspiration CAI students completed instruction in 23% less time, $t(1,38) = 9.13$, $p \leq .005$, than did lecture controls.

To summarize briefly, in addition to reading vocabulary aptitude, learner characteristics (e.g., self-concept, motivation, independence, and learner strategy preferences) were demonstrated to be significantly related to achievement and time savings in the three courses. Foremost among these learner characteristics from the standpoint of consistent relationships to differential performance was the motivational variable of achievement aspiration.

Comparative Failure Rates

Average failure rate in the three courses during the year prior to CAI intervention was moderately (22%) high. Indeed, one of the factors considered in course selection included course difficulty indices as reflected by average achievement attrition and failure rate. Failure rate in the present context was defined as the number of first attempt failures on the achievement test.

Comparative failure rates between CAI (2%) and PLT (14.9%) within the Radiology course were statistically significant, $\chi^2_1 = 7.77$, $p \leq .01$. Failure rates between CAI and lecture in the Medical Laboratory and Dental courses were not significantly different.

Student Attitudes

Student attitudes toward CAI prior to, during, and immediately after CAI, as gathered by the on-line scale, was, on the average, favorable and significantly different, $t(1,385) = 8.61$, $p \leq .001$ from neutral as shown in Figure 12. It is noted that no significant change in attitude was obtained at the pre, interim, or post-CAI, on-line measurement points.

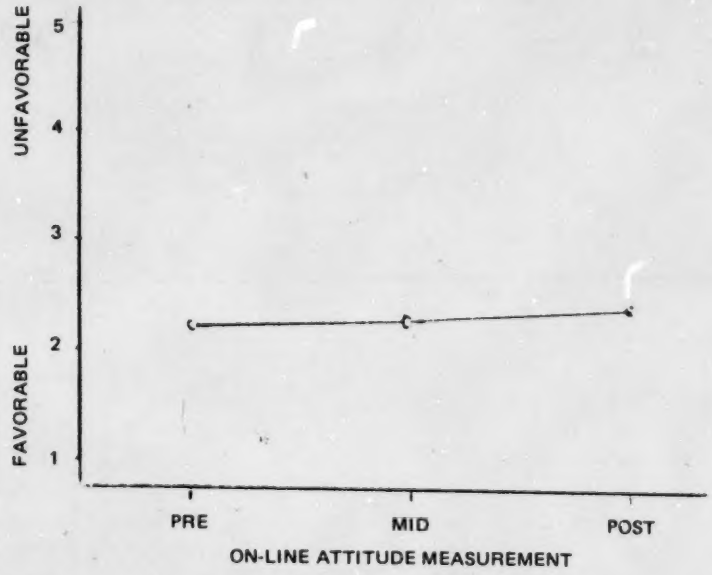

Figure 12. **On-line learner attitudes toward CAI immediately prior, during, and subsequent to CAI.**

In contrast, statistically significant attitude items obtained from the Delta Post-Instructional Attitude Questionnaire administered to CAI, PIT, and lecture students approximately 1 week after instruction revealed some interesting attitudinal comparisons as a function of experiencing CAI and non-CAI treatment conditions. Significantly more (χ^2_1 =15.32, p ≤.001) CAI students (50%) than controls (25%) tended to disagree with the statement that listening to a lecture was generally a better way to learn than reading self-paced materials. In contrast, significantly (χ^2_1 =12.53, p ≤.001) more CAI students (72%) than controls (51%) agreed they were motivated by the opportunity to complete instruction as quickly as possible. Likewise, significantly more (χ^2_1 =23.83, p ≤.001) CAI students (77%) than controls (31%) felt "they did a lot more doing than listening during instruction." Though a greater percentage (57%) of the controls agreed they needed more opportunities to practice what they were learning, significantly (χ^2_1 =6.94, p ≤.05) fewer (44%) CAI students agreed more practice was needed. Additionally, significantly more (χ^2_1 =6.63, p ≤.05) CAI students (89%) than controls (77%) agreed they learned best when a variety of visual examples were provided.

In comparing student attitudes toward alternative delivery systems (CAI, PIT, and lecture), the following data were obtained: 67% of the CAI students as opposed to 11% of the controls agreed that CAI, compared to lectures, was less boring (χ^2_1 =63.69, p ≤ .001) than lectures. Comparison of student attitudes toward CAI as opposed to PIT, indicated CAI was perceived as less boring (61%) than programmed text (19%) (χ^2_1 =39.26, p ≤.001). To complete attitudinal comparisons among instructional delivery alternatives, significantly (χ^2_1 =13.86, p ≤ .01) more (57%) CAI students than control (30%) agreed with the statement that "lectures were more boring than programmed text." However, it is noteworthy that more CAI students (78%) than controls (55%) agreed that CAI might be best used to teach basic material; whereas, "live" instructors should be used to lead seminar discussion groups to increase student understanding of critical subject matter (χ^2_1 =12.82, p ≤.002).

Analysis of post-instructional student attitudes within the CAI group solely, revealed a greater percentage (56%) of CAI students agreed than disagreed (32%) that it was more interesting to be taught by CAI than classroom lecture (χ^2_1 =4.88, p ≤ .05). Considering that only 21% of the students expected CAI to be more interesting than lecture prior to assignment to CAI or non-CAI conditions, significant positive attitude change toward CAI as a function of CAI experience was demonstrated (χ^2_1 =26.91, p ≤.001).

Moreover, a greater percentage of the CAI students agreed (58%) than disagreed (23%) that lessons were successfully completed faster at their own pace under CAI than under conventional classroom conditions (χ^2_1 =10.93, p ≤.02). The majority of CAI students (74%) also perceived that computer administered achievement tests were equally fair for all students (χ^2_1 =20.93, p ≤.01) due to computer objectivity. Interpretation of attitudinal results within the context of CAI/non-CAI conditions is deferred to the Discussion section of this report.

IV. DISCUSSION

To answer the question of whether CAI is instructionally more effective than PIT or lecture, independent of aptitude level, data were obtained (Appendix C) which supported the comparative instructional effectiveness of CAI in two of three courses in which CAI and non-CAI students were compared to identical instructional objectives. Overall, CAI student achievement exceeded student achievement mediated by (a) lecture by 13 percentage points and (b) PIT by 3 percentage points. In terms of comparative learning time independent of aptitude, CAI students averaged 12% to 17% less time than lecture or PIT students. Thus, if one were interested only in overall comparative instructional effectiveness (disregarding aptitude level in courses and for students comparable to

those employed in the present study), CAI is concluded to be more instructionally efficient than lecture or PIT in the Medical Laboratory and Radiology courses. Within the Dental course, no significant difference between CAI and lecture achievement was found; however, a 17% CAI time savings was obtained. To provide empirical data on the question of whether CAI, lecture, and programmed text differ in instructional effectiveness as a function of aptitude level, treatment by aptitude level comparisons were made. Results revealed that CAI yielded greater achievement and time savings than non-CAI at certain aptitude levels. Thus, the evidence affords an empirical basis for decisions pertaining to choices among alternative instructional modes based upon differences in instructional effectiveness and time savings.

Medical Laboratory

Within the Medical Laboratory course, CAI student achievement substantially exceeded Medical Laboratory lecture controls at all reading vocabulary aptitude levels. At the low aptitude level, CAI students excelled lecture controls by 18 percentage points. Probability of first attempt failure was extremely low ($p = .001$) for CAI students, as well as for lecture controls ($p = .03$).

In contrast to achievement findings, learner time to completion as a function of aptitude level revealed time savings exceeded 33% at the high aptitude level. Time to completion differences at the mid-aptitude level revealed an 11% CAI time savings, but no statistically significant time difference at the low aptitude level, compared to lecture controls. As noted previously, since CAI achievement was higher than lecture at all levels of reading aptitude, the obtained CAI time scores probably are much higher than required to reach a level of achievement equal to the lecture means.

Radiology

Achievement differences between CAI and PIT were shown to be related to aptitude level in the Radiology course. Both high and low aptitude CAI students achieved higher average scores than their high and low aptitude PIT counterparts. The effects of boredom may be one possible explanation of the lower-than-expected performance of PIT students compared to CAI students at the high aptitude level. Indeed, post-instructional attitudinal data indicated the majority of students perceived programmed text to be more boring than CAI. It is important to emphasize that programmed text had been the major instructional device employed in the last few weeks preceding the CAI-PIT comparison. In addition, failure rate was significantly less (2%) in the CAI condition, than in the PIT condition (14.9%).

Unlike Medical Laboratory course time-to-completion data, the greatest difference in time to completion between CAI and PIT occurred at the low aptitude level in the Radiology course. Low aptitude CAI students required 17% less time than their low aptitude PIT counterparts to complete instruction. Furthermore, CAI student completion time variability was considerably less ($Sd = 65$) than PIT time variability ($Sd = 101$). Such data suggest greater group variability in time to complete instruction is due in part to the problems of control of student time under conditions of self-paced programmed instruction. On the other hand, CAI apparently tends to keep students task-oriented through the structure and stimulation of interactive requirements.

To sum up the case of self-paced PIT vs. CAI, CAI is concluded to produce greater instructional effectiveness in 17% to 18% less time than PIT for low and high aptitude students. Furthermore, CAI was shown to produce time savings with 60% less time variability than PIT. Thus, the interactive control of CAI may be responsible for sustaining learner attention which leads to more rapid progress than PIT.

Dental

Though no statistically significant overall achievement score differences were obtained in the Dental course, aptitude stratification revealed a tendency for CAI students at the low aptitude level to achieve more (7%) than their low aptitude lecture controls. Unfortunately, in addition to less than desirable Dental course criterion reliability (r_{yy} =.58), the sample size at the low aptitude lecture level was small (N =7) in contrast to the low aptitude CAI student (N =30) sample.

Additional interpretations of the non-significant CAI-lecture instructional effectiveness difference findings in the Dental course may reasonably be attributed to the relative task difficulty level of the subject matter and to the learner characteristics differences in the Dental course relative to the more difficult Radiology and Medical Laboratory courses. Essentially, CAI as a compensatory tool may be more instructionally effective in difficult subject matter courses which require task-related aptitudes and motivation levels sufficient for processing/analyzing abstract information or learning complex procedures. Less difficult courses and/or insensitive criterion tests of lower reliability used to measure achievement differences are therefore less likely to demonstrate CAI achievement effects. In short, level of task difficulty confronting the learner, criterion reliability, and the learner's characteristics are factors of considerable importance when choosing among instructional delivery alternatives.

Time savings differences between CAI and lecture in the Dental course were found to be 29% at the high aptitude level and 15% at the mid-aptitude CAI levels. Thus, in the case of CAI vs. lecture in the most difficult (Medical Laboratory) and least difficult (Dental) courses, the following conclusions appear warranted: (a) to obtain significant time savings (29% to 33%), assign CAI to high aptitude students, (b) to increase achievement and reduce failures, assign CAI to low aptitude students, and (c) if CAI resources permit, assign CAI rather than lecture to high aptitude students in difficult courses comparable to the Medical Laboratory course to obtain increased time savings and instructional effectiveness.

Decision Strategies

Decision strategies for optimizing the effectiveness of instructional alternatives require analysis of (a) course-specific properties, (b) task-related learner characteristics, (c) student flow, (d) instructional alternative cost comparisons, and (e) trade-offs regarding levels of instructional effectiveness and time-to-complete instruction. If the training system is confronted with an increase in personnel with low reading vocabulary aptitude, first attempt failures may increase in conventionally taught courses, attended by an increase in time-to-complete instruction. If CAI is differentially assigned to lower aptitude students to increase achievement and minimize failure, the cost is little or no time savings. Conversely, if the goal is to maximize time savings, based upon data reported herein, CAI might profitably be assigned to high reading aptitude students, who are expected to complete instruction in 33% less time. However, opting for time savings is conducted at the cost of an increase in the probability of more failures and more marginally effective achievement at the lower aptitude level in the lecture mode. If CAI were assigned to all students, regardless of aptitude level, average student achievement is increased, but average time saving is reduced to approximately 13%.

Learner Characteristics

Foremost among the learner characteristics predictive of achievement and time-to-complete instruction successfully were the aptitude measures (Delta Reading Vocabulary, Concealed Figures, and Memory Measures). Despite differences among the courses on such factors as difficulty level,

type of learning, and mode of instruction, reading vocabulary emerged as the single best predictor of both achievement and completion rate. Such information further underscores the importance of reading vocabulary as one factor contributing to successful performance. Whereas aptitude measures were shown to be related significantly to subsequent learner performance in all three courses, biographical measures added significantly to prediction. Measures of achievement aspiration, self-concept, field independence-dependence, and learner strategy preferences for processing information varied in magnitude among courses, and therefore, in the order of contribution to achievement or completion time predictions. It is important to recall these biographical self-report pre-course measures maintained significant relationships to performance upon cross-validation. Depending on the course, one biographical measure of motivation (achievement aspiration) yielded significant performance relationships ($r = .29$ to $.39$) and resulted in main effect achievement differences ranging from 4 to 14 percent within the three courses. Hence, requiring students to set personal achievement goals yielded systematic and beneficial effects upon subsequent performance.

Similarly, field independent learners were found (a) to exceed the achievement of field dependent learners in the more difficult Medical Laboratory course by 6 percentage points and (b) to require 25% less time to complete instruction than their more field dependent peers. Thus, in accordance with theory and previous research, field independence has been shown to be related to performance in complex tasks. Perhaps equally as important, field independent learners are more likely to complete self-paced instruction faster (25% less time) than their more field dependent peers.

Another learner characteristic, self-concept, was also found significantly related to completion time. High self concept learners completed instruction in less time (23% to 32%) than learners with a low self-concept. Thus, self-perception in addition to other learner characteristics discussed herein would appear to be important variables in deciding whether an individual should be assigned to a self-paced program. Furthermore, self-concept may be used to identify learners for instructional strategies designed to systematically produce success, and thereby, an increase in a learner's self-worth. Nothing is likely to increase a person's low self-concept or subsequent effort more than the reward of success.

Learner strategy preferences from the Delta Biographical gathered prior to the course(s) were also found to be significantly related to subsequent performance. Preferences for active learning (e.g., paraphrasing as opposed to rote memorization or passive listening) resulted in greater performance for active learning strategies. Additionally, preference for interactive learning (e.g., discussion or peer instruction in contrast to more passive instruction, such as audiovisual or lecture) was found to be related to subsequent performance differences. For example, learners in the Medical Laboratory course who preferred active/interactive modes of learning tended to score 6 to 8 percentage points more than learners who preferred the potentially more passive lecture and audiovisual instructional modes. Similar findings which have been reported (Dansereau et al., 1975, 1978; Deignan, 1974) support and confirm the contribution of various learner strategies to subsequent performance. More importantly, the development of learner strategy skills in learners who use less effective methods of learning (Dansereau et al., 1978) would seem to be a promising cost-effective means of increasing proficiency if not also efficiency.

Characteristics of High Achievement-Fast CAI Learners

Characteristics of high achievement-fast CAI learners were obtained through discriminant analysis of high and low achievement scorers in the CAI condition of each course. Major variables found to correctly classify 85% ($\chi^2_{10} = 46.78$, $p \leq .001$) of high and low CAI achievers in the Medical Laboratory course included: (a) reading vocabulary, (b) learner strategy preferences for verbal paraphrasing as opposed to rote learning, (c) high as opposed to low self-concept, (d) high as contrasted with low level of achievement aspiration, and (e) preferences for reading as opposed to lectures. Major characteristics of CAI learners who completed instruction 25% faster ($\chi^2_{10} = 42.18$, $p \leq .001$) than their slower CAI counterparts included: (a) learners with relatively high reading

vocabulary scores, (b) higher educational level, (c) higher memory scores, (d) more field independence, (e) possessed higher achievement aspiration, and (f) were taught by a family member, as opposed to their teacher, to read. Within the Radiology course, CAI was instructionally more effective in 21% less time (χ^2_{10} =44.19, p ≤.001) for CAI learners who possessed high reading vocabulary, high achievement aspiration, were more field independent than dependent, and preferred verbal paraphrasing to rote memorization as a means of learning. Among these variables, CAI learners also reported on Delta Biographical pre-course measures they felt they had mastered instruction if they could teach a peer the same subject matter; whereas the slower, lower scoring CAI learners reported a greater reliance on lectures or audiovisual to learn.

Learner characteristics conducive to high CAI achievement in 20% less time in the Dental course as opposed to lower CAI achievement and slower time to completion under CAI differ only slightly in characteristics from the "high-achieving, fast burners" in the Medical Laboratory and Radiology courses. Variables which correctly classified 88% ($\chi2_{10}$ =46.49, p ≤.001) of the high and low CAI performers included relatively high reading vocabulary, preference for teaching a peer as a means of confirming their newly acquired knowledge, high achievement aspiration, pre-course preference for CAI as opposed to lecture modes, high self-concept, and eldest ordinal rank in one's immediate family.

To summarize the characteristics of high-fast CAI achievers in the three courses, it is concluded that (a) relatively high reading vocabulary skills, (b) high achievement aspirations to effect such skills, and (c) skills and attitudes underlying learner strategy preferences are instrumental to performance outcomes.

Thus, in addition to differentially assigning learners to alternative instructional delivery modes based upon aptitude, it is suggested that motivational factors, e.g., attitude, achievement aspiration, and learner strategies be considered.

High-Fast vs. Low-Slow PIT Students

Characteristics of learners for whom PIT was effective or ineffective were obtained through discriminant analysis of high and low achievement scores in the PIT condition. Variables found to correctly classify 82% (χ^2_8 =27.37, p ≤.001) of the high and low PIT achievers in the Radiology course included (a) level of achievement aspiration, (b) self-determination to succeed, (c) learner strategy preferences for reading good examples as opposed to preferences for audiovisual or lectures when instruction was difficult, and (d) higher versus lower reading vocabulary scores. Regarding time to completion, PIT learners who completed instruction in 23% less time than their slower PIT counterparts were identified correctly 72% (χ^2_7 =14.66, p ≤ .04) of the time by (a) level of achievement aspiration, (b) higher as opposed to lower self-estimate of memory capability, (c) more field independent than dependent, and (d) preference for working alone as opposed to working with others.

Based upon the foregoing data, PIT is likely to result in successful performance for students who possess high levels of motivation in addition to preference for, and high aptitude in, reading. In identifying learners who progress faster than their peers in self-paced PIT courses similar to the Radiology course, achievement aspiration, above average memory capabilities, independence, preference for working alone and, of course, adequate ability to read on one's own have been found to constitute learner characteristics contributing to faster, as opposed to slower, progress.

High vs. Low Achievement Lecture Students

Major learner characteristics obtained through discriminant analysis which correctly classified 85% (χ^2_{10} =30.85, p ≤ .001) of the high and low achievers in lecture included: (a) higher as opposed to lower achievement aspiration, (b) higher in contrast to lower reading vocabulary, (c) employed verbal paraphrasing as opposed to rote memorization as a learner strategy for acquiring knowledge, and (d) were more field independent than dependent.

Post Instructional Attitudes

Statistically significant data from the Delta Post-Instructional Attitude Questionnaires were not only important to determine the relative degree of acceptance or resistance toward CAI and non-CAI (lecture or PIT), but also provided some ancillary information of instructional interest. For example, concentration to learn under the CAI condition appeared to require no more effort than concentration required to learn under non-CAI conditions. Indeed, the data indicated a greater (74%) percentage of non-CAI students reported they had to really concentrate to learn than did counterpart CAI students (62%). Familiarization with the instructional medium, whether CAI, lecture, or PIT, however, was important; 65% of the CAI students and 61% of the non-CAI students indicated they really enjoyed their respective medium once they had become familiarized with it. Both CAI and non-CAI students also agreed (75% CAI, 65% non-CAI) instructional presentations provided enough visual examples for learning. However, more CAI students (89%) than non-CAI students (77%) agreed they learned best when a variety of visual examples was provided. In addition, the need for more opportunities to practice what was being acquired indicated that a smaller percentage of the CAI students (44%) as compared to non-CAI students (57%) agreed that more practice was needed. The interactive graphic capabilities of CAI for practice may account for the magnitude of this difference. Similarly, more CAI students (77%) than non-CAI students (31%) agreed they did a lot more doing than passive listening during instruction.

Considering the impact of learner boredom upon attitudes toward alternative instructional media, 67% of the CAI students in contrast to 11% of the controls, disagreed with the statement that CAI "was boring compared to lectures." Only 13% of the CAI students agreed CAI, compared to lectures, was boring. Student perception of boredom under CAI versus PIT conditions revealed that 61% of the CAI students and 19% of the controls agreed CAI compared to PIT was not boring. A small percentage (10%) of the CAI students regarded CAI more boring than PIT. To complete the comparative analyses among CAI, PIT, and lecture, 57% of the CAI students in contrast to only 30% of the controls regarded lectures more boring than PIT. However, 38% of the controls viewed PIT as more boring than lectures. In summary, CAI in comparison to lectures and PIT was less likely to be reacted to with feelings of boredom. The interactive, self-paced nature of CAI might reasonably explain why CAI was more resistant to feelings of boredom than PIT or lecture.

It is important to note that more CAI students (72%) than non-CAI controls (51%) agreed they were self-motivated by the opportunity to complete instruction as quickly as possible. In addition, more than twice as many CAI students agreed (58%) than disagreed (23%) that they perceived themselves to successfully finish lessons faster at their own pace with CAI than in the classroom. Achievement data indicated that the opportunity to complete instruction quickly did not adversely impact achievement compared to counterpart controls. To the contrary, CAI achievement was markedly superior to controls in two of the three courses. Hence, the opportunity to progress at the student's own pace under CAI conditions might be argued to facilitate achievement rather than retard it.

Learner Media Preferences

Preference among instructional media subsequent to media exposure indicated only 33% of the CAI students in contrast to 50% of the controls agreed that listening to a lecture was, in general, a better way to learn than reading self-paced (CAI) materials. In brief, twice as many CAI students (50%) preferred self-paced materials to lectures than did controls (25%).

To the extent learning tasks involved difficult material, CAI students differed markedly from control students in preferences among lecture, audiovisual, PIT and CAI. The majority (72%) of control students preferred lectures; whereas only 47% of the CAI students preferred lectures when material was difficult. Within the CAI condition solely, 31% of the students preferred CAI, 10%

audiovisual, 12% PIT, and 47% lecture when instructional material was difficult. Similarly, 40% of the CAI students reported they performed better with CAI than with lecture; whereas 43% believed lecture facilitated their performance more so than CAI. Based upon these data, students who had experienced CAI were approximately equally divided in terms of attitudinal reactions toward CAI and lecture. Some indication of why CAI students were divided on the question of whether CAI or lecture helped them perform better is perhaps explained in part by student responses to the following attitude item: 78% of the CAI students agreed, whereas only 16% disagreed, CAI might be best used in teaching basic knowledge and instructors subsequently used as discussion group leaders to ensure student understanding of critical subject matter. Given this frame of reference, the majority (78%) of students reflected a positive attitude toward CAI. However, students indicated when material was especially difficult or integration of critical subject matter to ensure understanding was needed, the security of having a "real live" discussion group instructor was needed.

Attitude Change

Considering that prior to assignment to CAI or non-CAI conditions, only 21% of the learners expected CAI to be more interesting than lecture, it is indeed noteworthy that subsequent to CAI experience, 56% of the CAI learners reported CAI was more interesting than lecture. Similar attitude change was found in the case of lecture; 56% of the learners to be later assigned to CAI expected lecture to be more interesting than CAI; whereas, after CAI exposure, only 32% felt lecture was more interesting than CAI. If a learner is to obtain the most from an instructional experience, an initial positive attitude is likely to increase learner skills employment and energize perception of the instrumentality of the situation for successful performance. Hence, it is recommended that all students to be assigned to an unfamiliar method (e.g., CAI) be provided with an orientation program prior to formal instruction to assist in making the unfamiliar, familiar (Toblas, 1976). Additionally, the simple act of setting achievement goals (achievement aspiration) was shown in the present investigation to be related significantly to subsequent performance.

In summary, the majority of CAI students perceived CAI to be more interesting, less boring, less time-consuming, and more instructionally effective than was lecture or PIT. However, when instructional material was especially difficult, CAI students were divided on preferences for lectures and CAI. Accordingly, the majority of CAI students agreed CAI should be employed to teach basic knowledge and instructors should be used to lead discussion groups to ensure student understanding of critical subject matter or methods. From the standpoint of student testing, however, more students agreed (74%) than disagreed (11%) "computer testing was impartial and therefore equally fair to all students." Hence, though approximately half of the CAI students preferred human instructors to CAI in complex subject matter areas, most of the students preferred the objectivity of the computer in student evaluation. In addition, prior to familiarization with CAI, only 21% of the learners preferred CAI to lecture in contrast to 56% who preferred lecture to CAI. Given this initial, less than enthusiastic attitude toward CAI, CAI students on the average performed better than their controls. As a classic example of attitude change as a function of subsequent experience, 56% of the CAI learners preferred CAI to lecture, post-instructionally.

V. CONCLUSIONS AND RECOMMENDATIONS

From an overall standpoint, CAI was found to be more effective than lecture or PIT. CAI was found to increase student achievement as much as 18 percentage points more than lecture controls, and 7 percentage points more than programmed text controls. Moreover, CAI student failure rates were considerably less than programmed text controls. Though high aptitude CAI students completed instruction in 30% less time than low aptitude CAI students, low aptitude CAI students

achieved greater instructional effectiveness in 17% less time than low aptitude programmed text controls. CAI time to completion was also 60% less variable than the self-paced programmed text completion time.

In the case of CAI vs. lecture, the following conclusions appear warranted: (a) significant time savings (23% to 33%) were achieved by students assigned to CAI, (b) low aptitude CAI students experienced greater achievement and less failure than their low aptitude lecture controls, and (c) student attitudes toward CAI became more favorable as a result of CAI experience.

Major characteristics of learners for whom CAI was more instructionally effective in less time included level of reading vocabulary, achievement aspiration, field independence, and learner strategy employed. Thus, performance differences in achievement and time can be expected to vary chiefly as a function of task-related learner characteristics, difficulty level, instructional medium assigned, and course-specific properties.

Empirical evidence has substantiated the comparative instructional and time savings effectiveness of CAI overall and at specific aptitude levels. Additionally, cross-validated learner characteristics yielded profiles found to distinguish high-fast as opposed to low-slow achievers in each course and treatment condition. Hence, given a self-paced environment, it is possible to differentially assign CAI to students for whom it is more effective.

For instructional situations similar to those in this study, it is recommended that CAI be used as a primary medium of instruction. If CAI resources are limited, CAI should be assigned to high aptitude students and to those students identified as marginal performers as measured by selected preassessment measures. Such measures should include reading vocabulary, learner strategy preferences, field independence-dependence, and achievement motivation.

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APPENDIX A: ACHIEVEMENT $\overline{X}$ AND SD BY APTITUDE, TREATMENT, AND COURSE

Course	Aptitude		CAI	Lec	PIT
Medical Laboratory	Low	$\overline{X}$	86.98	69.37	
		SD	12.48	12.21	
	Mid	$\overline{X}$	88.71	75.69	
		SD	14.55	12.02	
	High	$\overline{X}$	92.07	79.88	
		SD	11.93	14.87	
Radiology	Low	$\overline{X}$	83.67		76.67
		SD	8.80		11.90
	Mid	$\overline{X}$	84.05		86.50
		SD	8.05		8.33
	High	$\overline{X}$	88.12		78.50
		SD	6.92		8.02
Dental	Low	$\overline{X}$	73.39	66.35	
		SD	12.60	15.77	
	Mid	$\overline{X}$	76.59	79.32	
		SD	11.82	13.64	
	High	$\overline{X}$	84.25	82.71	
		SD	12.87	10.50	

APPENDIX B: TIME TO COMPLETION $\overline{X}$ AND SD BY APTITUDE, TREATMENT, AND COURSE

Course	Aptitude		CAI	Lec	PIT
Medical Laboratory	Low	$\overline{X}$	572.50	540	
		SD	244.20	0	
	Mid	$\overline{X}$	489.25	540	
		SD	205.05	0	
	High	$\overline{X}$	347.69	540	
		SD	170.06	0	
Radiology	Low	$\overline{X}$	262.33		315.54
		SD	52.01		106.75
	Mid	$\overline{X}$	250.76		237.24
		SD	62.13		63.08
	High	$\overline{X}$	186.85		226.80
		SD	46.54		86.89
Dental	Low	$\overline{X}$	496.80	540	
		SD	108.00	0	
	Mid	$\overline{X}$	456.43	540	
		SD	72.12	0	
	High	$\overline{X}$	386.95	540	
		SD	69.77	0	

APPENDIX C: MEAN PERCENTAGE ACHIEVEMENT AND MEAN TIME IN MINUTES TO COMPLETE INSTRUCTION IN THREE COURSES

Group	N	% Correct Achievement Score		Time to Complete Instruction (Min)	
		$\bar{X}$	SD	$\bar{X}$	SD
Medical Laboratory					
CAI	93	88.94	13.51	469	220
Lecture	98	75.12	13.84	540	0
Radiology					
CAI	97	84.72	8.14	240	65
PIT	89	81.95	10.62	271	106
Dental					
CAI	101	77.03	13.58	453	95
Lecture	52	78.07	14.01	540	0

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